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THE GRAIN BUG.[1]

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INTRODUCTION.

During the past few years the grain bug, (*Pentatoma*) *Chlorochroa sayi* Stål, has become a pest of considerable importance to the farmers of the intermountain and southwestern States. It is now regarded as a serious menace to the growing of wheat and other small grains in both the irrigated and nonirrigated districts within the area of its distribution.

The vital damage is caused by the piercing of the newly formed heads of cereals and the feeding on the liquid contents, by which the formation of the grain is prevented or its weight greatly reduced.

The recent development of *C. sayi* as an economic pest is due to an artificial change in its environment and food plants. This condition has been brought about by the cultivation of large areas formerly devoted to grazing, which practically eliminated many of the native food plants and caused the insect to attack some of the crops grown in its former habitat. The change to more succulent food plants, together with the better facilities for hibernation in the cultivated areas, resulted in a marked increase of the pest.

[1] The observations detailed in this bulletin were made by the senior author in 1915 and by the junior author in 1916 during a destructive outbreak of the species in northeastern New Mexico and adjacent territory. The experiments were carried on at the Field Laboratory of the Bureau of Entomology located at Maxwell, N. Mex.

Mr. E. H. Gibson, of the Bureau of Entomology, kindly redescribed the adult of the species and assisted in the preparation of notes on the history, synonymy, distribution, food plants, and bibliography.

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Weather influences and the work of parasites in each locality where damage has occurred generally have restricted the destructive outbreaks of *C. sayi* to periodic intervals of two or three years. Since 1911, however, its activities have been reported with increasing frequency each year in widely separated districts within its range. This development indicates clearly the possibility that the species may become economically more important in the future than it has been in the past.

HISTORY.

The grain bug belongs to the rather extensive heteropterous family Pentatomidae, the members of which are popularly known by the expressive term of "stink-bugs." It was first authentically described under the name *Lioderma*, subg. *Chlorochroa*, *sayi* by Stål (1)[1] in 1872. In the same year Uhler (2) described a species under the name *Pentatoma granulosa*, which later proved to be synonymous with Stål's *L. sayi*. In 1904 Van Duzee (3) placed the species in the subgenus Chlorochroa of the genus Pentatoma. In 1909 Kirkaldy (4) placed the subgenus Chlorochroa under the genus Rhytidolomia. In 1916 Van Duzee (7) removed Chlorochroa from Rhytidolomia and raised it to generic rank, listing the species under consideration as *Chlorochroa sayi* Stål.

The first recorded damage by *Chlorochroa sayi* is found in the unpublished notes of the Bureau of Entomology, several farmers of the upper Gila and Salt River Valleys of Arizona having reported it, in May, 1903, as very destructive to wheat and barley. One farmer wrote that there was an average of about 10 bugs to each head of barley in his 40-acre field. After badly damaging this area the insects had moved to an adjoining wheat field, these conditions being typical for a distance of about 30 miles along the upper Gila Valley. In reply to an inquiry by Dr. L. O. Howard the following note was received on June 5, 1903, from Dr. R. H. Forbes, director of the Arizona Agricultural Experiment Station: "We have kept track of the outbreak of *Lioderma sayi* in Arizona. The worst outbreak was upon the upper Gila River, between Safford and Fort Thomas, but a great many specimens were also to be found in the Salt River Valley." In July of the same year reports of damage and specimens of the insect were received from the San Juan Valley in southwestern Colorado. In 1905 and 1906 this species was very numerous in the wheat fields of northern Texas, but no widespread damage was reported. Dr. A. W. Morrill (6) published an account of the complete loss of 13 acres of milo maize near Phoenix, Ariz., in September, 1911, as a result of depredations by

[1] Figures in parentheses refer to "Literature cited," p. 34.

C. sayi. During this same period Mr. V. L. Wildermuth observed severe damage to milo maize in the Imperial Valley of California.

In May, 1912, Mr. C. N. Ainslie received specimens of *Chlorochroa sayi* and accounts of injury to the heads of spring wheat from a correspondent at Tucumcari, N. Mex. Mr. Ainslie also notes that while making field investigations in Utah during 1912 the farmers in four widely separated districts of the State reported that the grain bug had seriously damaged wheat and alfalfa seed during the years immediately prior to 1912.

Mr. H. E. Smith records widespread damage to barley and oats in the Pecos River Valley of New Mexico during 1912 and 1913. At the same time Mr. E. G. Kelly found similar conditions prevailing in the "dry-farming" section near Clovis, N. Mex., and in the vicinity of Liberal, Kans.

In July, 1913, a correspondent wrote from Cloudcroft, N. Mex., that the grain bug had ruined 12 acres of rye on his ranch and that the farmers of that section had cut the barley for hay to prevent the destruction of its grain by the invading hordes of the insect. Similar damage was reported from southern Utah during the same month. In 1914 and 1915 continued reports were received of depredations by the grain bug from various localities in Arizona, New Mexico, Texas, and Colorado.

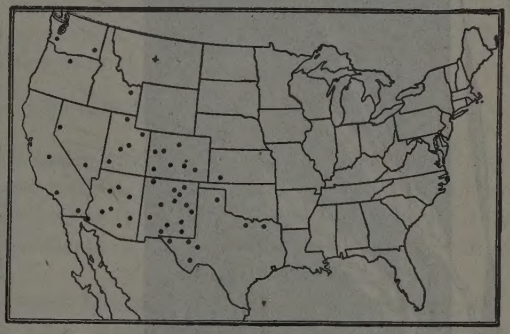

FIG. 1.—Map showing distribution of the grain bug (*Chlorochroa sayi*) in the United States. The dots indicate definite localities; the cross in the State of Montana is based on the statement of Van Duzee (3) that his study material included specimens from Montana. He does not indicate the locality.

DISTRIBUTION.

In the United States *C. sayi* is distributed generally throughout the Upper and Lower Austral zones of the States west of the Great Plains area, including Washington, Oregon, California, Idaho, Nevada, Montana, Utah, Colorado, Arizona, New Mexico, western Kansas, and the western and northern parts of Texas. (See fig. 1.) These data were secured from personal collections in the field and by an examination of the collections, notes, correspondence, and literature of the United States National Museum and the Bureau of Entomology, as well as from other available literature.

The insect is found at varying altitudes ranging from 9,300 feet at Silverton, Colo., to below sea level in the Imperial Valley of California.

FOOD PLANTS.

The nymphs and adults of *C. sayi* have been observed to feed upon the fruit and seeds of a wide range of cultivated plants, including wheat, barley, rye, oats, winter emmer, spelt, milo maize, kafir corn, feterita, alfalfa, Sudan grass, cotton, buckwheat, peas, beans, cabbage, tomato, and lettuce. Among the native food plants of the species are Russian thistle (*Salsola tragus* L.), mallow (*Malva parviflora* L.), pigweed (*Amaranthus* spp.), wild oats (*Stipa* spp.), lamb's-quarters (*Chenopodium* spp.), sheepweed (*Gutierrezia* spp.), and a species of the honeysuckle (*Lonicera involucrata* Banks).

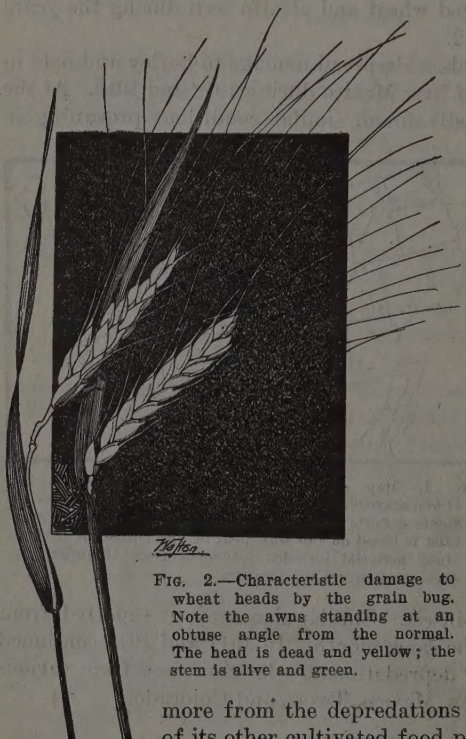

FIG. 2.—Characteristic damage to wheat heads by the grain bug. Note the awns standing at an obtuse angle from the normal. The head is dead and yellow; the stem is alive and green.

Wheat, barley, and rye appear to suffer more from the depredations of *C. sayi* than do any of its other cultivated food plants.

CHARACTER OF INJURY.

EXTERNAL APPEARANCE OF INJURED PLANTS.

The heads of small grains that have been injured by *C. sayi* are conspicuous in the field, especially those of wheat, barley, rye, and oats. Soon after attack, and long before the normal period of ripening is reached, the damaged heads assume a dull yellowish-white color and in this condition are in sharp contrast to the bright green of the undamaged heads. They appear normal in size with the ex-

ternal appearance of ripened heads, but upon being pressed between the fingers are found to be nearly, if not entirely, empty. With the bearded varieties, the "beards" or awns stand out nearly at right angles from the head instead of in the vertical position assumed under normal conditions. (See fig. 2.)

The stem is generally alive and green from the base to a point within 5 or 6 inches of the head, but is dead and yellow above this point. Upon grasping the head and exerting a slight pull, the stem breaks at the junction of the living and dead portions. During a wind or rain storm many of these stems are broken and the heads fall to the ground. The damage caused by *C. sayi* is frequently of such a nature that an unobserving person may attribute its effects to hail or other weather influences.

In the case of milo maize, feterita, and many of the native food plants, the external appearance of injured plants does not differ markedly from that of the normal.

INTERNAL APPEARANCE OF INJURED HEADS.

The grains of affected heads are shriveled in appearance and very much reduced in size and weight. In some cases only a diminutive grain remains. This follows as the natural result of the removal by the insect of the liquid contents of the grain while still in the "milk stage."

The grains from injured heads of some plants, including milo maize, appear normal even when damaged, but are very much reduced in weight, lack the nutritive properties of normal grains, and are totally unfit for seed.

REDUCTION IN YIELD.

The percentage of reduction in yield through depredations of the grain bug is a point not always possible of determination. Frequently the extent of the damage is not appreciated by the grower until the crop is thrashed. Then the poor quality of the grain becomes evident and the yield is far below expectations. In extreme cases entire fields of small grains have been destroyed completely and the crop was not worth harvesting. As previously stated, Dr. A. W. Morrill (6) records the complete loss of 13 acres of milo maize from grain-bug attack at Phoenix, Ariz., in 1911, and 12 acres of rye were completely ruined at Cloudcroft, N. Mex., in 1913. From 70 to 90 per cent of an alfalfa seed crop was destroyed at Barstow, Tex., in 1911. Mr. H. E. Smith records that at Roswell, N. Mex., in 1913, at least two-thirds of the barley heads were ruined in fields that normally would yield from 40 to 60 bushels per acre. At Porterville, Tex., in 1913, the wheat in a 150-acre field which promised a

yield of from 50 to 60 bushels, thrashed only 22 bushels of very inferior grain per acre.

During 1915 when the grain bug was under close observation in northeastern New Mexico the visible damage before harvest varied in many of the fields from only a trace to 50 per cent of the heads, the average being about 10 per cent. The full extent of the damage was not appreciated until harvest, when the poor quality, reduced yield, and light weight of the grain were sources of general complaint among the farmers. In one instance under consideration a carload of oats averaged only 18 pounds per bushel.

FIG. 3.—The grain bug: Eggs. Above, much enlarged; below, highly magnified.

DESCRIPTION.

THE EGG.[1]

Length 1.1 to 1.2 mm.; width at widest part 0.88 to 0.93 mm.; width at bottom 0.57 to 0.66 mm. The egg (fig. 3) is irregularly ovoid in form, with irregular gray areas on the lateral surface, in appearance resembling froth. Viewed from above, three white circles appear, inclosing a central dull-gray area and two circular bands of the same color.

Described from 15 eggs taken from as many different clusters.

NYMPHS.[1]

FIRST INSTAR.

Length 1.1 to 1.54 mm.; width of thorax 0.88 to 0.935 mm.; width of abdomen 0.935 to 1.072 mm.

Dorsally: Head black, finely punctate, anterior margin sparsely pubescent; eyes black, prominent; antennæ 0.77 to 1.88 mm. in length, light brown, three terminal segments sparsely pubescent. Thorax black, finely punctate, with deep convolutions between its divisions and down the median line. Abdomen brown-black in color, middorsal section occupied by a narrow black band; location of scent glands indicated by two black transverse areas; a single black area within a yellow border on the lateral margin of each segment and a series of three irregular yellow-white markings converging toward the apex of the abdomen. The lateral margins of the abdomen and thorax are greatly depressed and form a shelf-like division between the ventral and dorsal surfaces. This is distinct from the connexivum of adult Heteroptera. The "shelf" persists throughout the nymphal period. Edge of "shelf" sparsely pubescent in this instar.

FIG. 4.—The grain bug: Nymph, first instar. Much enlarged.

[1] Original description.

Ventrally: Color uniform black, divisions of "shelf" white, rostrum light brown, extending three-fourths length of venter; legs black. The legs are sparsely pubescent in all stages of the insect.

Described from 15 specimens.

SECOND INSTAR.

Length 2.2 to 2.53 mm.; width of thorax 1.21 to 1.275 mm.; width of abdomen 1.54 to 2.117 mm.

During the development of the nymphs in the second instar a change occurs in the color, markings, and pubescence which is not accompanied by any visible molt. The description of the nymphs in the early stages of this instar (fig. 5) follows:

FIG. 5.—The grain bug: Nymph, second instar (in early stages of the instar). Much enlarged.

Dorsally: Head black, finely punctate, sparsely pubescent throughout; eyes dark brown, prominent; antennæ 1.375 to 1.485 mm. in length, light salmon or brown, three terminal segments sparsely pubescent. Thorax black, coarsely punctate, sparsely pubescent on dorsum and at edge of "shelf"; four irregular yellow-white areas on anterior borders of prothorax and mesothorax, with two small dots of same color on posterior border of mesothorax; "shelf" white. Abdomen black, with a pale yellow double band extending transversely across the anterior border and becoming enlarged near the margin; posterior to this band the mid-dorsal section is occupied by five irregular bands of the same color and two brown, slightly raised, elongated, elliptical areas bearing the scent glands; posterior margin sparsely pubescent; "shelf" white.

FIG. 6.—The grain bug: Nymph, second instar (in later stages of the instar). Much enlarged.

Ventrally: Uniform black except the white "shelf"; rostrum light brown, extending three-fourths length of venter; legs black.

The following changes are observed in late stages of this instar (fig. 6):

Dorsally: Head pubescent only on anterior border, anterior half impressed with two parallel sutures on each side of median line. These parallel sutures persist in all the remaining stages of the insect. Antennæ black. Thorax with a faint tinge of green, no pubescence, finely punctate, no yellow-white areas. Abdomen with decided tinge of green; a narrow transverse yellow-white band occupying two-thirds of the anterior border, and posterior to this band the mid-dorsal section occupied by a small circular yellow-white area, two curved bands of the same color, and two wider black irregularly ovoid areas, bearing the scent glands; "shelf" red-orange.

Ventrally: "Shelf" red-orange on the abdomen.

Described from 15 specimens.

THIRD INSTAR.

Length 3.08 to 3.19 mm.; width of thorax 1.925 to 2.035 mm.; width of abdomen 2.365 to 2.805 mm.

Dorsally: Head black, finely punctate, slightly pubescent; eyes black, prominent; antennæ 1.925 to 1.98 mm. in length, black, two terminal segments very finely pubescent. Thorax black with distinct tinge of green, coarsely punctate; "shelf" white during early stage of instar, later becoming orange in color. Abdomen dark green and bearing approximately the same markings as later stages of preceding instar, and black coarse punctations; segmentation emphasized by black lines in this and in the remaining nymphal instars; "shelf" orange color.

FIG. 7.—The grain bug: Nymph, third instar. Much enlarged.

Ventrally: Head and thorax green. Abdomen pale green, a black circular area on each of the four terminal segments; anal opening black. These black areas persist on the venter of the remaining nymphal instars. "Shelf" orange on both thorax and abdomen. Rostrum green, extending slightly more than one-half length of venter. Legs: Coxæ, trochanters, and femora green; tibiæ and tarsi brown.

Described from 7 specimens.

FOURTH INSTAR.

Length 5.2 to 6.6 mm.; width of thorax 3.1 to 3.75 mm.; width of abdomen 3.8 to 4.9 mm.

Dorsally: Head pale green, finely punctate; eyes reddish black, not so prominent as in preceding instars; antennæ 3.4 to 3.7 mm. in length, dark brown or black. Thorax pale green with darker coarse punctations; wing pads visible as slightly raised areas on both sides of thorax; "shelf" white with a red-orange edge. Abdomen pale green; punctations numerous, coarse and darker green in color; a narrow yellow transverse band occupying one-half median portion of abdomen on anterior border, and posterior to this band the mid-dorsal section occupied by a short narrow yellow band, four circular areas of the same color, and two brown crescentic projections bearing the scent glands; black coarse punctations more numerous than in preceding instar; "shelf" white with red-orange edge.

FIG. 8.—The grain bug: Nymph, fourth instar. Much enlarged.

Ventrally: Uniform pale green, with black punctations. "Shelf" orange on both thorax and abdomen. Rostrum green with brown tip and extending one-half the length of venter. Legs: Coxæ, trochanters, and femora pale green; tibiæ and tarsi light brown.

Described from 11 specimens.

FIFTH INSTAR.

Length 8.9 to 10.6 mm.; width of thorax 4.3 to 4.8 mm.; width of abdomen 5.3 to 7 mm.

Dorsally: Head pale green, finely punctate; eyes brown, surrounded by pale green area; antennæ 4.5 to 5.2 mm. in length, black or brown, peduncle light green, articulation of segments pale green. Thorax green with black punctations; wing pads black or nearly so; "shelf" white to orange. Abdomen pale green with black punctations and bearing approximately the same marking as preceding instar; "shelf" white with more pronounced orange edge than on thorax, not so prominent as in preceding instars.

Ventrally: Same as the preceding instar. Rostrum extending to posterior coxæ. Legs: Tarsi and outer fourth of tibiæ black, remaining portions of legs pale green, tarsi and tibiæ bearing numerous black spines.

Described from 15 specimens.

FIG. 9.—The grain bug: Nymph, fifth instar. Much enlarged.

THE ADULT.

The following is the description by Stål (1).

5. L[ioderma] (Chlorochroa) Sayi STÅL.—Ovalis, dilute viridis, subtus pallidior, superne pectoreque sat dense distincteque punctata, ventre subtilius punctato; antennis nigris, articulo basali virescente; limbo laterali antico thoracis, limbo costali thoracis, apice scutelli, margine abdominis, coxis, trochanteribus femoribusque basin versus pallide sordide flavescentibus; callis rugulisque parvis sparsis, in thorace scutelloque obsoletis, in corio distinctioribus, nec non maculis tribus laevigatis subcallosis basalibus scutelli viridi-albicantibus; membrana alisque decoloribus; marginibus imis lateralibus anticis thoracis et margine imo abdominis lutescentibus; tarsis apicem versus fuscis. ♀. Long. 11, Lat. 6 1/3 mill.

Patria: California. (Mus. Holm.).

Praecedenti affinis, notis allatis formaque angustiore divergens.

A redescription of the adult, by Mr. E. H. Gibson, of the Bureau of Entomology, is given below.

Distance between eyes equaling almost two-thirds length of head. Head closely punctate above. Tylus and juga of the same length. Anterior margin

of head slightly reflexed or cariniform. First antennal segment less than one-half as long as second; second, third, fourth, and fifth segments of nearly the same length, the second slightly the longest and most slender. Bucculæ long and prominent. Rostrum extending to hind coxæ.

Pronotum coarsely punctured and appearing somewhat rugose. Lateral margins reflexed or cariniform. Callosities prominent.

Scutellum coarsely punctured and appearing somewhat rugose, like the pronotum. Three large prominent callosities on anterior border, one at each anterio-lateral angle, and one at the middle. Apex bluntly rounding.

Elytra more finely punctured than scutellum with many small callous spots. Membrane clear.

General form elongate. Average size of female 13.5 mm.; males somewhat smaller. The general size varies considerably.

FIG. 10.—The grain bug: Adult. Much enlarged.

Color normally a decided deep green, but varying from a pale yellowish green to reddish brown. Numerous small white calloused spots on pronotum, scutellum, and elytra. Lateral border of pronotum, basal portion of costal border of elytra, the three large callouses on anterior border of scutellum, and apex of scutellum yellow or red. As noted, the color varies greatly but the numerous light colored callous spots are characteristic. Antennæ black except for basal segment and basal half of second segment, which are green. Pale yellowish green beneath. Abdomen above black except borders, which are yellow and unmarked.

LIFE HISTORY AND DEVELOPMENT.

The observations on the life history and development of *Chlorochroa sayi*, as detailed herein, were made at an altitude of about 6,000 feet in northeastern New Mexico. These details probably would vary considerably under the different conditions of humidity, latitude, and altitude within the distribution of the insect.

EGG.

PERIOD OF INCUBATION.

The period of incubation is from 4 to 13 days in length, depending upon weather influences, the average throughout the season being about 9 days. During the warm summer months the egg period occupies an average of from 5 to 7 days.

RELATION OF TEMPERATURE TO INCUBATION.

In laboratory experiments and in the field it was observed that variations in temperature had a pronounced influence in determining the length of the egg period. In one experiment half of a newly deposited egg cluster hatched in 4 days when exposed to a maximum daily temperature of 90° F. while the remaining half of the same egg cluster which was exposed to a maximum daily temperature of 70° F. required 7 days to complete its period of incubation. (See Table I.)

TABLE I.—*Relation of temperature to incubation and nymphal development in Chlorochroa sayi.*

	Incubation period.	First instar.	Second instar.
	Days.	*Days.*	*Days.*
Maximum daily temperature of 70° F.	7	9	14
Maximum daily temperature of 90° F.	4	4	7
Difference for 20° F. of temperature	3	5	7

DETAILS OF HATCHING.

When nearly ready to hatch, the eggs assume a darker color than during the earlier stages of their development. Upon dissecting one of these eggs it is found that the fully developed nymph is inclosed within a delicate transparent membrane. On the outside of this membrane just under the lid of the egg, and at a point opposite the vertex of the head of the inclosed nymph, is a black, chitinized T-shaped structure which functions as a shell burster. The curved top of the T, or shell burster, follows a curved line running from eye to eye of the nymph over the vertex of the head. The shank of the T follows the median dorsal line of the nymph posteriorly. A short, stout spine occupies about one-third of the median portion of the T at the point where the lines intersect. This spine is directed at the suture between the lid and the neck of the egg at a point opposite its hinge. During the process of hatching the struggles of the nymph against the shell burster exert a strong lifting pressure on this spine and the lid of the egg is partially raised. At the same time the inclosing membrane splits just back of the shell burster and slips forward over the head of the nymph. As the integument of the nymph is very soft, the emergence is by slow periodic movements apparently exerted from within the body of the nymph. The first portion of the nymph to be free is the first pair of legs, followed by the antennæ, rostrum, second pair of legs, third pair of legs, head, thorax, and abdomen in the order named.

In observations on the hatching of 8 individual nymphs, the time required for emergence varied from 14 to 40 minutes, the average being 20 minutes. The newly hatched nymph is capable of locomotion soon after completing emergence but generally remains on or near its parent egg cluster until the second instar is reached. All normal eggs in the same egg cluster generally hatch within a 24-hour period.

PROPORTION OF EGGS HATCHING IN THE FIELD.

Unless destroyed by parasites or predacious enemies, the proportion of eggs of *Chlorochroa sayi* hatching in the field is very high. Occasionally a few eggs in otherwise normal clusters were prevented from hatching by being deposited wrong end up. A few eggs, too, were deposited on top of the main egg cluster, which invariably prevented the lower eggs from hatching. Very few infertile egg clusters were collected in the field. Abnormal weather conditions prolonged the period of incubation but appeared to have no other injurious effects on the eggs.

PROPORTION OF EGGS HATCHING IN THE LABORATORY.

In one laboratory experiment a total of 1,068 eggs were deposited by 30 females confined in life-history cages. Of this number a total of 981 eggs, or 91.88 per cent, hatched. The remaining 8.12 per cent were probably somewhat affected by the abnormal cage conditions.

NYMPHS.

DURATION OF NYMPHAL STAGES.

The prevailing temperature conditions have a marked influence in controlling the duration of the nymphal stages of *Chlorochroa sayi* in the field and in life-history cages. During the period from July 5 to August 18, 1916, a total of 17 nymphs were reared from egg to adult. (See Table II.) In this series of cages the first instar occupied 5 days; the second instar, from 7 to 9 days with an average of 8.2 days; the third instar, from 5 to 7 days with an average of 6.4 days; the fourth instar, from 7 to 10 days with an average of 8.2 days; and the fifth instar occupied from 13 to 17 days, the average being 14.9 days. From 42 to 44 days were required to complete the nymphal period, the average being 42.7 days.

TABLE II.—*Duration of nymphal instars of Chlorochroa sayi in period from July 5 to August 18, 1916.*

Female No.	Nymphs hatched.	First molt.	First instar.	Second molt.	Second instar.	Third molt.	Third instar.	Fourth molt.	Fourth instar.	Fifth molt to adult.	Fifth instar.	Total nymphal period.
			Days.		*Days.*		*Days.*		*Days.*		*Days.*	*Days.*
1	July 5	July 10	5	July 19	9	July 24	5	Aug. 1	8	Aug. 16	15	42
2	do	do	5	do	9	do	5	do	8	do	15	42
3	do	do	5	do	9	July 25	6	do	7	Aug. 17	16	43
4	do	do	5	July 17	7	July 24	7	do	8	Aug. 16	15	42
5	do	do	5	do	7	do	7	do	8	Aug. 18	17	44
6	do	do	5	July 18	8	July 25	7	Aug. 3	9	Aug. 17	14	43
7	do	do	5	July 19	9	do	6	Aug. 1	7	Aug. 16	15	42
8	do	do	5	July 18	8	do	7	Aug. 2	8	Aug. 17	15	43
9	do	do	5	July 19	9	do	6	Aug. 3	9	do	14	43
10	do	do	5	July 18	8	do	7	do	9	do	14	43
11	do	do	5	do	8	do	7	Aug. 2	8	do	15	43
12	do	do	5	do	8	do	7	do	8	Aug. 18	16	44
13	do	do	5	do	8	July 24	6	Aug. 1	8	Aug. 17	16	43
14	do	do	5	do	8	July 25	7	Aug. 3	9	Aug. 16	13	42
15	do	do	5	do	8	July 24	6	do	10	Aug. 17	14	43
16	do	do	5	do	8	do	6	Aug. 1	8	Aug. 16	15	42
17	do	do	5	do	8	July 25	7	Aug. 2	8	Aug. 17	15	43
Averages			5		8.2		6.4		8.2		14.9	42.7

Later in the season during a period of cooler weather, from August 10 to September 30, 1916, the duration of the nymphal stages of 25 nymphs averaged 7 days for the first instar, 14 days for the second instar, and 18 days for the third instar. (See Table III.) This series of experiments was discontinued on October 3.

TABLE III.—*Duration of nymphal instars of Chlorochroa sayi in period from Aug. 16 to Sept. 30, 1916.*[1]

No.	Nymph hatched.	First molt.	First instar.	Second molt.	Second instar.	Third molt.	Third instar.
			Days.		*Days.*		*Days.*
1	Aug. 16	Aug. 23	7	Sept. 7	15	Sept. 22	15
2	do	do	7	Sept. 6	14	Sept. 23	17
3	do	do	7	Sept. 7	15	Sept. 27	20
4	do	do	7	do	15	Sept. 23	16
5	do	do	7	Sept. 6	14	do	17
6	do	do	7	Sept. 5	13	Sept. 22	17
7	do	do	7	Sept. 7	15	Sept. 26	19
8	do	do	7	Sept. 8	16	do	18
9	do	do	7	Sept. 6	14	Sept. 24	18
10	do	do	7	Sept. 5	13	Sept. 23	18
11	do	do	7	Sept. 7	15	Sept. 28	21
12	do	do	7	do	15	Sept. 26	19
13	do	do	7	Sept. 5	13	Sept. 25	20
14	do	do	7	Sept. 7	15	Sept. 26	19
15	do	do	7	do	15	Sept. 30	23
16	do	do	7	Sept. 6	14	Sept. 24	18
17	do	do	7	do	14	Sept. 26	20
18	do	do	7	Sept. 7	15	Sept. 25	18
19	do	do	7	do	15	Sept. 22	15
20	do	do	7	do	15	Sept. 25	18
21	do	do	7	Sept. 6	14	Sept. 23	17
22	do	do	7	Sept. 7	15	Sept. 22	15
23	do	do	7	Sept. 6	14	Sept. 25	19
24	do	do	7	do	14	Sept. 22	16
25	do	do	7	Sept. 8	16	Sept. 27	19
Averages			7		14.5		18.08

[1] Discontinued Oct. 3, 1916.

Similar results were obtained as a result of life-history experiments during 1915.

The death rate of nymphs under observation in the laboratory was very high and increased the difficulty in obtaining data on the length of the different stages, but it is believed that the durations of the instars given above coincide very closely with the actual periods occupied by the nymphs in the field.

DETAILS OF MOLTING.

When the nymph is preparing to molt it generally assumes a position with the head downward. After a quiescent period varying from 15 to 50 minutes the process of molting begins. The thorax first splits down the median dorsal line, then the integument connecting the dorsal plates of the head and thorax splits transversely, allowing the head to fall forward. The thoracic region now becomes elevated, as a result of pressure exerted from within, and the split in the molting skin more pronounced. This causes a transverse separation of the integument connecting the dorsal plates of the thorax and abdomen to a point nearly as far as the lateral edges of the dorsal thoracic sclerites. The molting nymph first extracts the head and its appendages and then the first, second, and third pairs of legs. As soon as the legs are free they are used as a lever in extracting the remainder of the thorax and abdomen from the molted skin. In four instances under observation the process of molting required from 9 to 12 minutes.

The newly molted nymph appears to be prepared to resume its activities within a few moments after the completion of its molt.

With the exception of the ruptures noted above, the cast nymphal skin remains intact and greatly resembles a living nymph.

RELATION OF TEMPERATURE TO NYMPHAL DEVELOPMENT.

In order to determine the relation of temperature to nymphal development an equal number of nymphs hatching at the same time from the same egg cluster were kept under maximum daily temperatures of 70° and 90° F., respectively. The nymphs developing under the lower temperature required an average of 5 days longer for the first instar and 7 days longer for the second instar. (See Table I.) It is evident that cool weather retards nymphal development to a marked degree.

ADULTS.

PERIOD BETWEEN MATURITY AND BEGINNING OF OVIPOSITION.

The ovaries of newly matured females do not contain eggs. In a series of laboratory experiments wherein pairs of reared adults were confined in individual cages, the minimum period between maturity

and oviposition was 41 days. This is probably longer than the period required under field conditions, judging from the number of generations each year. The females maturing late in the season do not oviposit until the following spring.

PROPORTION OF SEXES.

Under field conditions the females of *Chlorochroa sayi* are slightly more abundant than the males. In a total of 564 adults, collected from various habitats throughout the active season, 313 were females and 251 were males. (See Table IV.)

TABLE IV.—*Proportion of sexes of Chlorochroa sayi in different habitats throughout the active season.*

Date.	Habitat.	Number of males.	Number of females.	Total adults.
1916				
May 9	Under rubbish	6	12	18
May 10	....do	81	94	175
May 13	....do	1	4	5
May 16	....do	5	13	18
June 29	....do	4	4	8
June 30	Wheat heads	28	22	50
July 12	Under Russian thistle of previous year	12	6	18
July 14	On wheat heads	5	8	13
July 20	On wheat and thistle	3	4	7
July 24	....do	6	5	11
Aug. 1	On Russian thistle in waste areas of recently cut wheat field	10	12	22
Aug. 2	....do	9	20	29
Do.	On oat heads		6	6
Aug. 3	On Russian thistle	3	9	12
Aug. 4	....do	12	11	23
Aug. 17	....do	8	8	16
Aug. 24	....do	2	8	10
Sept. 28	In winter quarters	2	6	8
Sept. 29	....do	20	20	40
Oct. 2	....do	34	41	75
Total		251	313	564

LONGEVITY OF REARED ADULTS.

A series of reared adults kept in life-history cages lived a minimum of 19 days and a maximum of 48 days after maturity. The females lived for a longer period than the males. The longevity of these individuals as adults was undoubtedly influenced by the unnatural conditions under which they were reared to maturity.

LONGEVITY OF ADULTS COLLECTED IN FIELD.

In a series of 93 life-history cages, each containing a pair of adults of *Chlorochroa sayi* collected in the field, the females lived a maximum of 78 days with an average of 33 days and the males a maximum of 66 days with an average of 23. Under field conditions the adults undoubtedly live for three or four months, while the adults of the last two generations remain in a dormant condition in their hibernating quarters all winter.

DURATION OF LIFE WITHOUT FOOD.

The life of the adult is very short when deprived of food during its period of normal activity in summer temperatures. Five pairs of adults confined without food under a daily maximum temperature of 75° to 85° F. began dying on the second day and all were dead at the end of the fifth day. Under the same circumstances five pairs of adults kept under a daily maximum temperature 15° lower began dying on the fifth day and all were dead at the end of the ninth day. During hibernation the body of the adult contains much fatty tissue which apparently acts as a reserve food supply.

SEASONAL DEVELOPMENT.

SEASONAL HISTORY.

In the latitude of northeastern New Mexico the adults of *Chlorochroa sayi* emerge from hibernation during the first warm days of late April or early May. At this time the ovaries of the females contain fully developed eggs, and if mild weather conditions prevail these eggs are deposited within a few days on the underside of the rubbish or other material composing the hibernating quarters.

The resulting nymphs feed and develop upon the young sprouts of Russian thistle or other plants which have developed early in the season under the protection of the accumulated rubbish. Upon reaching maturity, about the last week in June, the adults of this first generation and the survivors of the overwintering brood migrate to the fields of grain and feed upon the tender stems and developing heads until the grain ripens. It is during this period that most of the economic loss from the grain bug occurs. The females of this generation usually deposit their eggs on the underside of rubbish in the field, or on Russian thistle growing along the ditches, fence rows, or waste areas. Occasionally eggs are deposited on different parts of the host plant, notably the awns or beards of the head, but as a rule the female seems to prefer the underside of some object near the ground. The newly hatched nymphs from these eggs have not been observed to feed upon the cultivated crops, but apparently depend upon weeds, especially Russian thistle, for their sustenance until reaching the third or fourth instar.

The second generation is completed about the same time that the majority of the grain crops are harvested, during the first week in August. The surviving adults and large nymphs of the first two generations then migrate to fields of late grain, milo maize, Sudan grass, volunteer grain, or other food plants which then are developing heads. If none of these crops is present, the insects confine their feeding to any of the native food plants growing in the vicinity.

The individuals of the third generation, progeny of these adults, feed on the late grain crops, or on their native food plants, and reach maturity about the middle of September.

A very large percentage of the third-generation females do not oviposit until the following spring, but during favorable seasons a few of the earliest maturing individuals of this generation sometimes deposit eggs from which adults of a partial fourth generation develop, although most of the nymphs do not reach maturity.

With the advent of cold weather, in October or November, the surviving adults of the later generations seek hibernating quarters for the winter. Many nymphs in all stages of development also enter hibernation at this time but do not survive the winter.

SUMMARY OF SEASONAL HISTORY.

Hibernating adults deposit eggs during late April or early May.

First-generation nymphs feed on native plants and develop to maturity in late June. Adults migrate to grain fields and feed on developing heads.

Second-generation nymphs feed on native plants or grain heads and develop to maturity in late August. Adults migrate to fields of late grain or feed on native plants.

Third-generation nymphs feed as in the preceding generation and develop to maturity by the middle of September. Adults feed mostly on native plants.

A partial fourth generation develops on native plants and matures just before the advent of cold weather.

Adults of the second, third, and fourth generations enter hibernation during late October or early November. Nymphs enter hibernation but do not survive the winter.

NUMBER OF GENERATIONS.

In the section where these observations were made there are three distinct generations each year and sometimes a partial fourth generation. The broods overlap considerably and all stages of the insect may be found in the field from the middle of May until the species enters its hibernation quarters in October or November.

SEASONAL ABUNDANCE.

The adults of the grain bug are very numerous locally during the time of their emergence from hibernation in April and May. In one instance 30 adults were found under a single "cow chip" about 6 inches square; and a total of 175 adults were found under the dead weeds along a 20-foot space of an irrigation ditch. The period of greatest abundance occurs, however, after the development of the second generation in late June and during July. At this time many

fields of small grain have been observed in which the adults and nymphs averaged 4 or 5 to each head of grain. On several occasions a quart of the insects was swept within a space of five minutes. After the middle of July the numbers of each succeeding generation are greatly reduced by the activities of parasites and predacious enemies until at the end of the season it is sometimes very difficult to find specimens of the insects, or their eggs, in fields where they were formerly abundant.

HABITS OF NYMPHS.

GREGARIOUSNESS AND POWERS OF LOCOMOTION.

During the first instar the young nymphs are gregarious in habit and seldom leave the proximity of their parent egg cluster. Soon after the second instar is reached they may wander away singly in search of food, but usually are found feeding very close together. During the third and succeeding instars the nymphs become more solitary in habit, but if the food supply is abundant the entire progeny of one egg cluster may reach maturity within a few feet from the place of their incubation, and under exceptional circumstances they sometimes complete their development on the same plant. The nymphs are rather slow of movement and they lack the power of flight, but in cases of necessity the larger nymphs may crawl several hundred feet in search of food.

FEEDING.

The nymphs when feeding assume a position with the legs strongly braced against the plant, the head upward or downward. The setæ of the mouth parts are inserted at right angles to the body and the liquid contents of the host are removed by suction. In the case of small grains the nymphs remove the entire contents of each kernel through a single puncture, but when feeding on tender stems several punctures are made within short distances of each other. Apparently the nymphs can not pierce any plant tissue after its epidermis has become hardened.

In the early spring the nymphs of all stages feed upon Russian thistle but later in the season a large percentage of the fourth and fifth instar nymphs feed, with the adults, on the tender stems and developing heads of grain. The larger nymphs have also been observed feeding on the tender stems and newly formed seeds of alfalfa, but experiments demonstrated that the species could not be reared from egg to adult on this plant. Throughout the season the young nymphs of the first three instars appear to confine their attention almost exclusively to Russian thistle, and when other food plants are lacking the nymphs of the last two instars feed upon this plant.

DAILY ACTIVITY.

In calm and fair weather the nymphs of *Chlorochroa sayi* are active and feeding (see Table V) during the period from about 8 a. m.[1] until the heat of the sun becomes oppressive an hour before noon. Then they seek the shelter of some object and remain quiet until the heat of the sun abates, resuming their activity and feeding from about 2 p. m. until the atmosphere cools in the late afternoon. During the night, and the cooler periods at the beginning and end of each day, the nymphs remain inactive and generally seek some protected location. The same is true during periods of high winds or rainy weather.

TABLE V.—*Daily activity and feeding habits of nymphs of Chlorochroa sayi, July 15, 1916.*

Time.	Temperature.	Weather.	Observation.
A. M.	° *F.*		
4	63	Cloudy	
4.30	62	Cloudy	
5	62	Sunrise	
5.30	64	Cloudy	Resting.
6	69	Cloudy	Resting.
6.30	69	Partly cloudy	Resting.
7	72	Cloudy	Resting.
7.30	73	Cloudy	Resting.
8	74	Fair	Feeding.
8.30	76	Fair	Feeding.
9	78	Fair	Feeding.
9.30	80	Fair	Feeding.
10	82	Fair	Feeding.
10.30	83	Fair	Feeding.
11	86	Fair	Feeding.
11.30	87	Fair	Feeding.
M.			
12	88	Fair	Feeding.
P. M.			Resting.
12.30	91	Partly cloudy	Resting.
1	90	Cloudy	Resting.
1.30	93	Cloudy	Resting.
2	94	Quite cloudy	Feeding.
2.30	97	Quite cloudy	Feeding.
3	90	Quite cloudy	Feeding.
3.30	88	Quite cloudy	Feeding.
4	88	Quite cloudy	Feeding.
4.30	83	Quite cloudy	Feeding.
5	82	Quite cloudy	Feeding.
5.30	80	Quite cloudy	Feeding.
6	80	Less cloudy	Resting.
6.30	80	Less cloudy	Resting.
7	79	Less cloudy	Resting.
7.30	77	Less cloudy	Resting.
8	76	Quite cloudy	Resting.
9	73	Quite cloudy	Resting.

In discussing the feeding and activity of the nymphs, it should be understood that in the high altitudes of northeastern New Mexico the nights are very cool, even during the summer months, while high temperatures are recorded at midday.

The inactivity of the nymphs during certain periods, together with their habit of dropping to the ground and feigning death when approached, frequently leads many unobserving owners of damaged

[1] All references to clock time refer to "Standard time."

grain fields to underestimate the numbers of this species present, and very often the resulting damage is attributed to other causes.

HIBERNATION.

Although large numbers of nymphs enter hibernation quarters with the adults, they soon perish and in no instance have they been observed to survive the winter.

HABITS OF ADULTS.

COPULATION.

The adults of *Chlorochroa sayi* are found in copulation on the food plants, under rubbish, or around the bases of plants at all times of the day and night. The mating pairs face in opposite directions and the length of copulation varies from a few minutes to several hours. In one life-history cage a pair was observed in copulation for two entire days and it is probable that they had continued in this position throughout the intervening night. On several occasions, when observed in copulation on their food plant, either one or both of the sexes continued to feed during the act.

OVIPOSITION.

Oviposition occurs at any time of the day or night whenever the female happens to be resting or feeding. When ovipositing the legs are strongly braced and the abdomen is inclined at an angle, nearly touching the object on which the eggs are deposited. As each egg is forced through the ovipositor, the tip of the abdomen bends and deposits the egg in its appointed position. Normally the eggs in the lower end of a cluster are deposited first and with these as a foundation the succeeding eggs are added in transverse rows. (See fig. 3.) The intervals between the deposition of individual eggs in a cluster average about one minute, so that the total time required for oviposition depends upon the size of the egg cluster.

LOCATION OF THE EGG CLUSTERS.

The egg clusters of *Chlorochroa sayi* are found in a great variety of locations, but generally are placed on the lower side of some portion of the food plant or underneath some object in the vicinity. The adults emerging from hibernation deposit their eggs on the rubbish or dead plants comprising the hibernating quarters, but the adults of the succeeding generations generally select the living food plant, or its close vicinity, for egg deposition. On different occasions egg clusters have been found on various parts of the food plant, including the awn or "beard," the edges of the leaves, the head of beardless varieties, the upper and lower sides of the leaves, and the stem. Other locations selected for egg deposition were the lower side of "cow chips," clods of earth, stones, and tin cans, and the wire and posts of fences. On one occasion an egg cluster was found super-

imposed on a cylindrical cluster of eggs of the New Mexico range caterpillar (*Hemileuca oliviae* Ckll.) that had been deposited around a sunflower stem.

NUMBER OF EGGS IN EACH CLUSTER AND THEIR DISPOSITION.

Counts were made of 185 typical egg clusters collected in the field during 1915 and 1916. The number of eggs in individual clusters varied from 13 to 43, the average being about 26. The smallest egg cluster consisted of 9 eggs and the largest, apparently deposited by a single female, consisted of 75 eggs. No uniformity was apparent in the number of eggs composing each cluster. This is a deviation from the published records, which indicate that in closely allied species there exists a uniformity in the number of eggs in each cluster.

The eggs are deposited with considerable regularity in two or four parallel rows, each egg being placed in the alternate space between the eggs of the adjoining row (see fig. 3), and each row consisting of from 7 to 20 eggs. This tendency is particularly marked when plant stems or the awns of grain heads are selected for egg deposition. Frequently when eggs are deposited on the broad surface of an object the formation of the cluster is very irregular.

NUMBER OF EGGS DEPOSITED BY EACH FEMALE.

The females normally do not deposit their full complement of eggs at one time or in a single cluster. Twenty-one newly matured females collected in the field early in the season and placed in confinement deposited a maximum of 107 and a minimum of 9 eggs, the average being 54 eggs from each female. These eggs were deposited in from 1 to 10 clusters over periods extending from 1 to 16 days. (See Table VI.)

TABLE VI.—*Oviposition habits of confined females of Chlorochroa sayi.*

Female No.	Total number of eggs.	Number of separate clusters.	Number of eggs in each cluster.	Average number of eggs in each cluster.	Days between first and last oviposition.
1	91	5	53–3–7–14–14	18.1	16
2	56	1	56	56	----
3	32	1	32	32	----
5	60	6	3–4–6–41–1–2	10	5
9	62	3	59–1–2	20.2	1
10	43	2	4–39	21.5	1
12	107	5	56–30–11–4–6	21.2	10
16	11	2	8–3	5.5	2
17	16	1	16	16	----
18	58	5	43–2–4–7–2	11.3	6
19	55	3	32–19–4	18	3
20	56	2	28–28	28	11
21	53	2	40–13	26.5	3
22	9	3	3–3–3	3	4
23	67	2	34–33	33.5	2
24	97	4	46–13–12–26	24.2	13
25	43	3	2–28–13	14.3	3
26	61	6	16–9–33–1–1–1	10.1	11
27	43	1	43	43	----
28	71	2	60–11	35.5	9
30	43	10	31–2–1–1–1–1–1–1–2–2	4.3	2

On May 10, 1916, 25 females were collected from winter quarters and dissected for egg counts. The maximum number of eggs per female was 56, the minimum 16, and the average 37. The ovaries of each female also contained many eggs which had not yet reached their full development.

DURATION OF FERTILITY.

The duration in the fertility of females varies greatly with different individuals. In some instances the full complement of the female apparently is deposited at one time, and this fact accounts for the large number of eggs occasionally found in single clusters. Generally, however, the period of oviposition extends from a week to 20 or 30 days and during this time the female deposits from 2 to 6 or 7 small egg clusters. (See Tables VI and VII.) The latter is apparently the normal habit and explains the fact that the average egg cluster found in the field is smaller than the average capacity of normal females.

TABLE VII.—*Oviposition habits and duration of fertility of confined females of Chlorochroa sayi. Record started May 10, 1916.*

Female No.	Date eggs were deposited.																	
	May.																June.	
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3
1	....	3	....	....	....	....	....	53	.....	....	7	.....	.....	....	14	....	....	14	....	.....
2	....	....	....	....	....	....	....	....	56	....	....	.....	.....	....	....	....	....	....	....	.....
3	....	....	....	....	....	....	....	....	.....	32	....	.....	.....	....	....	....	....	....	....	.....
5	....	....	....	....	....	....	....	....	3-4	....	....	6-44	....	1-2	....	....	....	....	....	.....
9	....	....	....	....	....	....	....	....	.....	1-2	59	.....	....	....	....	....	....	....	....	.....
10	....	....	....	....	....	....	....	....	.....	....	4	39	....	....	....	....	....	....	....	.....
12	....	....	....	....	....	....	....	....	.....	56	....	.....	....	....	....	....	....	....	30	11-4-6
16	....	....	....	....	....	....	....	....	.....	....	....	.....	8	....	....	3	....	....	....	.....
17	....	....	....	....	....	....	....	....	16	....	....	.....	.....	....	....	.....	....	....	....	.....
18	....	....	....	....	....	....	....	....	.....	43	....	.....	2-4	....	....	7-2	....	....	....	.....
19	....	....	....	....	....	....	....	....	.....	32	....	19	4	....	....	....	....	....	....	.....
20	28	....	....	....	....	....	....	....	.....	....	....	28	....	....	....	....	....	....	....	.....
21	....	....	....	....	....	....	40	....	.....	13	....	.....	.....	....	....	....	....	....	....	.....
22	....	....	....	....	....	....	....	....	3	....	....	3	3	....	....	....	....	....	....	.....
23	....	....	....	....	....	....	....	....	.....	34	....	33	.....	....	....	....	....	....	....	.....
24	46	....	....	....	....	....	....	....	13	....	....	12	26	....	....	....	....	....	....	.....
25	....	....	....	....	....	....	....	....	.....	2	26	.....	15	....	....	....	....	....	....	.....
26	16	....	....	....	....	....	....	....	9	33	1	1-1	....	....	....	....	....	....	....	.....
27	....	....	....	....	....	....	....	....	43	....	....	.....	.....	....	....	....	....	....	....	.....
28	....	....	....	....	....	....	....	....	60	....	....	.....	.....	....	....	....	....	....	....	11
30	....	....	....	....	....	....	....	....	{1-1-1- 1-1-1- 2-31	}	....	2-2	....	....	....	....	....	....	....	.....

The ovaries of females dissected late in the autumn or in early winter contain no eggs, but the abdomen is filled with a large amount of fatty tissue. Fertilization is probably accomplished during the last stages of hibernation in the very early spring and eggs develop within a short time. The ovaries of 25 females taken from hibernation in March were found to contain an average of 37 eggs and many additional immature eggs were present.

DAILY RATE OF OVIPOSITION.

The daily rate of oviposition varies considerably with individual females of the same age confined in life-history cages under identical conditions of food and environment.

Normally several days elapse between the deposition of each egg cluster, but occasionally a female deposits several small egg clusters on the same day, and frequently one or more egg clusters are deposited by the same female on successive days. (See Table VII.)

RELATION OF TEMPERATURE TO OVIPOSITION.

The amount of oviposition in the field is not noticeably affected by the ordinary ranges of summer temperatures, because many of the egg clusters are deposited by the females when they are in hiding during the cool periods of the day or during inclement weather. Probably, however, the greater percentage of the eggs is deposited during the warmer parts of clear days when the females are actively feeding.

FEEDING.

PARTS OF PLANTS PREFERRED.

The grain bug exhibits a marked preference for the juices of the seeds and fruits of its food plants and apparently feeds upon the tender stems and leaves only when more favored portions of the plants can not be obtained.

In grain fields the feeding is confined to medium sized and rapidly growing heads of immature seed. After the grain reaches the "dough" stage the insect ceases to feed upon it. Whether it does so because it prefers other food, or because the hardening of the glume containing the seed prevents the entrance of the setæ which constitute its piercing mouth parts, is not known.

METHOD OF ATTACK.

The adults attack and damage their food plants in much the same manner as has been previously described for the nymphs. The selected portion of the plant is pierced and its liquid contents removed by suction. The adults are very active in searching for the fruit or seeds of their food plants, and the total amount of damage caused by the insect in this stage is much greater than during the nymphal period.

CONSPICUOUS APPEARANCE WHEN FEEDING OR RESTING.

The grain bug adults are very conspicuous objects in the field, owing to their large size and tendency to seek the upper part of each plant, when feeding or resting on the grain heads. On clear days

the sunlight is reflected from the dorsal surfaces of the insects and adds to their conspicuous appearance. At this time at least 95 per cent of the adults present in the vicinity may be seen without moving any part of the plants. When disturbed, however, most of the adults immediately drop to the ground and seek cover.

ODOR AND EXCREMENT.

The characteristic odor of the adults and nymphs is not generally noticeable in the field even when the insects are present in large numbers. During thrashing operations, however, many farmers have reported that the odor given off by the grain bug was so noticeable as to cause much discomfiture to the workers. This was probably due to the fact that large numbers of the insects had concentrated about the grain shocks and had given off the offensive odor when disturbed. In life-history cages this offensive odor is not noticeable unless the insects are roughly handled.

The excrement of *Chlorochroa sayi* is a yellow-green fluid and is commonly found on the leaves or stems of the host plant. It varies in size from mere specks deposited by the young nymphs to circular masses 5 millimeters in diameter deposited by the adults.

DAILY ACTIVITY.

During the calm, pleasant weather of the summer months the adults of *Chlorochroa sayi* are active and feeding throughout the greater part of the day and night. They are not affected by the excessive heat of midday, as is true of the nymphs, but are more active and do most of their feeding while high temperatures prevail. (See Table VIII.) During periods of high winds, rain, or hail storms and nightly temperatures below 60°, the insects cease their activities and seek shelter, generally under some object on the ground or around the bases of their food plants.

TABLE VIII.—*Daily activity and feeding habits of adults of Chlorochroa sayi, July 15, 1916.*

Hour.	Temperature.		Wire cage 3 by 3 by 3 feet over wheat plot—2 male and 4 female adults.	
	Shade.	Sun.	Weather conditions.	Observation on activity.
A. M.	°F.	°F.		
4	63		Cloudy	5 on heads in same position as at 9 p. m. last night; at least 2 have setæ inserted into grain head.
4.30	62			Do.
5	62		Sunrise; cloudy	4 resting.
5.30	64		Cloudy	4 resting.
6	69			2 resting.
6.30	69		Partly cloudy	3 resting.
7	72		Cloudy	Do.
7.30	73			3 resting and feeding.

TABLE VIII.—*Daily activity and feeding habits of adults of Chlorochroa sayi, July 15, 1916*—Continued.

Hour.	Temperature.		Weather conditions.	Observation on activity.
	Shade.	Sun.		
	Wire cage 3 by 3 by 3 feet over wheat plot—2 male and 4 female adults.			
A. M.	°*F.*	°*F.*		
8	74	.....		2 feeding.
8.30	76	.....	Clear	3 feeding.
9	78	106		2 feeding.
9.30	80	114		Do.
10	82	118	Clear; wind rising	None feeding.
10.30	83	116	Clear	2 feeding.
11	86	104		3 feeding.
11.30	87	114		Do.
M.			Clear; slight wind	4 feeding.
12	88	117		
P. M.				
12.30	91	111	Partly cloudy; slight wind	Do.
1	90	114	Partly cloudy; no wind	Do.
1.30	93	107		5 feeding.
2	94	104		Do.
2.30	97	102	Cloudy	Do.
3	90	94		Do.
3.30	88	90		3 feeding.
4	88	88		Do.
4.30	83	84	Cloudy; slight wind	4 feeding.
5	82	82		5 feeding.
5.30	80	87	Clearing; less wind	4 feeding.
6	80	80		Do.
6.30	80	.....	Clearing; no wind	5 feeding.
7	79	.....		5 feeding and resting.
7.30	77	.....		Do.
8	76	.....	Clear; no wind	Do.
9	73	.....		Do.

Observations made at various times during the night indicate that the adults continue feeding after the daylight hours, providing that the temperature remains high enough for them to continue their activities.

PREDACIOUS AND CANNIBALISTIC HABITS.

In life-history cages the grain-bug adults frequently fed upon the contents of their own eggs. Under these same conditions the adults also fed upon the dead bodies of their companions and upon the issuing dipterous parasite larvæ. Apparently these predacious and cannibalistic habits are abnormal, as no observations of a similar character were made in the field, where on all occasions the nymphs and adults were observed to feed exclusively upon plants.

GREGARIOUSNESS.

The grain bug exhibits a marked degree of gregariousness in hibernation and to a more limited extent during its period of activity in the field. In May, 1916, a total of 30 hibernating adults were found under one "cow chip" about 6 inches square, and in the same vicinity 175 adults were collected from underneath the rubbish along a 20-foot space in an irrigation ditch. When feeding in the field they appear to prefer certain food plants to the exclusion of others of the same kind and in the same stage of development. This characteristic fre-

quently results in the concentration of 6 or 8 individuals on one grain head while similar plants in the vicinity receive but slight attention from the species. When large numbers of the insects are present in fields of wide area the adults appear to concentrate in certain portions of the field and change their location as the food supply becomes exhausted.

It is problematical whether this gregarious habit exhibited by the grain bug is a result of an attraction between the individuals or is largely stimulated by the presence of attractive food during its period of feeding and by superior facilities for protection during its inactive periods.

FLIGHT.

Generally the adults are very sluggish flyers and their flight is limited to a short distance. When disturbed they habitually drop to the ground for the purpose of seeking concealment without attempting flight. Under special conditions, however, the adults are capable of long and sustained flight. On June 30, 1916, large numbers of the adults were present on a small plot of wheat growing in the insectary grounds at Maxwell. The day was very warm, with no wind, and at this time when disturbed the adults took to flight and gradually ascended to a height of from 10 to 30 feet in the air, from this altitude maintaining a straight course as far as the eye could follow. Similar observations have been made in the field from time to time, and it is probable that these migrations generally are traceable to the need of a fresh food supply.

The adults have not been observed in flight during windy days, but the fact that they commonly migrate to the leeward side of the field at these times would indicate that their general line of flight was in the same direction as the prevailing wind.

On October 2, 1916, during a windy period, large numbers of adults were found feeding on the Russian thistle growing in the northeast corner of an abandoned wheat field. The wind was from the southwest, and although the adults were found in small numbers throughout the field, most of them apparently had been driven to their present location by the prevailing wind.

HIBERNATION.

The grain bug hibernates exclusively in the adult stage. No immature forms have been observed to survive the winter, although many of the larger nymphs enter hibernation with the adults and live for a short time.

LOCATION OF HIBERNATING QUARTERS.

In general, *Chlorochroa sayi* hibernates under and among dead weeds or rubbish, in crevices under the loose bark of trees or posts,

and around the bases of large uncut tufts of native grasses. The luxuriant growth of dead Russian thistle along irrigation ditch banks, fence rows, and roadsides, as well as piles of débris in the fields or pastures, affords ideal hibernating quarters for the insect. In cleaning out any of these habitats during the spring, it is not unusual to find scores of the adults concentrated within a very limited space. This circumstance at once suggests a simple and effective method for controlling the pest.

The hibernating adults apparently lack the power to burrow beneath the surface of the soil. Generally they are found directly underneath the material composing their hibernating quarters or in loose material on the surface of the ground.

MORTALITY DURING HIBERNATION.

In some localities there is a high percentage of adult mortality during hibernation. Frequently in the spring large numbers of dead individuals are found grouped together with only a very few living forms remaining. Under these circumstances it is probable that the hibernating quarters were exposed to unusually severe conditions and did not afford the contemplated protection from winter temperatures. It is also possible that parasites, predators, or fungous diseases occasionally may be responsible for the high rate of mortality.

Under more favorable conditions for hibernation it is not uncommon to find that among hundreds of adults at least 95 per cent have survived the winter.

Severe winters undoubtedly result in the death of a large percentage of hibernating adults and form one of the most important factors in restricting destructive outbreaks of the species.

CHANGE OF COLOR DURING HIBERNATION.

In hibernation the adults of *Chlorochroa sayi* change to a greenish-pink color, quite distinct from their normal summer appearance. This change is not evident in the autumn when the adults are seeking their winter quarters or in the spring directly after they have emerged from hibernation. Adults collected in the autumn and kept active throughout the winter in a stove-heated room assumed the same characteristic color as the inactive adults in outdoor hibernating quarters. The specimens reverted to their normal coloration in the spring. Possibly this change in the appearance of the species during the summer and winter seasons may serve as protective coloration.

The winter coloration persists in the pinned museum specimens of adults collected from hibernation.

NATURAL ENEMIES.

PARASITES.

During the course of the investigations in New Mexico one proctotrypid parasite, *Telenomus ashmeadi* Morrill, was reared from the eggs of *Chlorochroa sayi*, and two tachinid parasites, *Gymnosoma fuliginosa* Desv. and (*Ocyptera*) *Ocypterodes euchenor* Walk. were reared from the adults of the species.

PARASITES OF THE EGG.

The egg parasite *Telenomus ashmeadi* (fig. 11) constitutes one of the most effective natural agents in the control of *Chlorochroa sayi* and is very widely distributed throughout the area infested by the pest. During the latter part of July and the early part of August, in 1915, adult parasites emerged from about 60 per cent of the eggs collected in badly infested fields. In many egg clusters a parasite emerged from each and every egg. In all instances under observation it has been noted that nymphs rarely hatch from an egg cluster when any of the individual eggs produce parasites. Upon dissection these unhatched eggs generally are found to contain dead parasites or to be nearly devoid of contents, apparently the result of parasitism. It is evident from the foregoing that the percentage of eggs from which adult parasites emerge does not necessarily indicate the full total of parasitism in the field.

FIG. 11.—*Telenomus ashmeadi*, an egg parasite of the grain bug. Greatly enlarged. (Morrill.)

On July 27, 1916, a dozen reared parasites were confined in a glass vial with a freshly deposited egg cluster of *C. sayi*. Within two minutes the females began ovipositing. During this process the female stands on the two posterior pairs of legs with the body nearly vertical and inserts her short ovipositor into the egg, meanwhile bending the head and antennæ forward. They prefer to oviposit in the top of the egg or in the side of the egg near its top. On August 13 the adult parasites began emerging from this egg cluster, a total of 17 days being required to complete the life cycle of the parasite

in this instance. In a similar experiment started on August 17, 1915, the duration of the life cycle was 26 days.

The comparatively short life cycle of *T. ashmeadi* enables the species to complete several generations each year and greatly increases its value as a parasite.

PARASITES OF THE ADULT.

Field collections made from various and widely separated localities during 1915 and 1916 demonstrated that in some fields nearly 25 per cent of the adults and last-instar nymphs were parasitized by the tachinid fly *Gymnosoma fuliginosa*.

FIG. 12.—*Gymnosoma fuliginosa*, a fly parasite of the grain-bug adult. Much enlarged.

According to Morrill (5) the female of this species usually deposits her eggs near the margin of the body on the ventral prothoracic region of the adults and fifth-instar nymphs. The manner in which the resulting larva enters the body of its host has not been observed. The body contents are consumed within a short time and the fully developed parasite larva makes an exit through the anal opening of its host and enters the ground for pupation. The period of pupation for 24 individuals reared during the summer of 1916 varied from 6 to 15 days, the average period being 11.4 days.

The parasitized insect retains its activity and powers of destructiveness up to within a short time before the parasite is due to emerge. This characteristic detracts somewhat from the value of *G. fuliginosa* and renders it of less importance than the egg parasite

Telenomus ashmeadi in the natural control of *C. sayi*. Frequently death does not occur until several hours, or even days, after the parasite has left the body of its host, the host meanwhile remaining inactive.

Although eggs are deposited on the nymphs, no instances were observed in which the larvæ of *G. fuliginosa* completed their development and issued before the host reached its adult stage.

The seasonal history of *G. fuliginosa* corresponds very closely with that of *C. sayi* and there are the same number of generations annually. The adults are engaged actively in parasitizing *C. sayi* throughout

FIG. 13.—*Ocypterodes cuchenor*, a fly parasite of the grain-bug adult. Much enlarged.

the period of activity of the host, extending from April to October or November. They are most numerous during the months of July and August, and at this time a dozen or more individuals have been collected by a few sweeps of the net in fields that were heavily infested with *C. sayi*.

The parasite hibernates, in some instances at least, as a larva within the body of its host. In February, 1916, during severe winter weather, 25 adults of *C. sayi* were collected from hibernation at French, N. Mex., and placed in a heated room. They became active within a few hours and 3 days later 2 larvæ of *G. fuliginosa* issued. These larvæ were placed in a pupating cage and the resulting adults emerged 16 days later. It is probable that the parasite also hibernates as a puparium

beneath the surface of the ground, as many individuals in this stage have been dug from the soil underneath the hibernating quarters early in the spring. This fact was not definitely established, however, owing to the difficulty encountered throughout the winter in examining the frozen soil of these locations.

Eight specimens of the tachinid *Ocypterodes euchenor* Walk. were reared from several hundred adults of *Chlorochroa sayi* kept in confinement during 1916. The species has been observed infrequently in the field and must be considered of only minor importance in the natural control of *C. sayi*. Its life cycle and habits, as far as observed, were very similar to those of *Gymnosoma fuliginosa*.

PREDACIOUS ENEMIES.

The offensive odor secreted by the scent glands of *Chlorochroa sayi* has been commonly supposed to protect them from the attacks of predatory enemies. While this odor may act as a repellent to some of its enemies, in the case of *C. sayi* the different stages of the insect are preyed upon by quite a variety of both vertebrate and invertebrate enemies. Considered individually these enemies are not of great importance in the control of the pest, but in the aggregate they undoubtedly exert considerable influence in the reduction of its numbers.

PREDATORY INSECTS.

The adults of the malachiid beetle *Collops bipunctatus* Say feed upon the eggs of *Chlorochroa sayi* in the field. This small beetle is very numerous in the grain fields of New Mexico and apparently is one of the most effective predatory enemies of the grain bug. In confinement a single adult of this species devoured in one day an egg cluster consisting of 10 eggs, consuming even the eggshells. The same individual, however, refused to feed upon small nymphs of *C. sayi*.

When confined in cages the adults of *C. sayi* frequently fed upon their own eggs, but this habit has not been observed in the field.

The adults of *Sinea spinipes* H. S. and of *Phymata erosa* Stål have been observed feeding upon the nymphs of the grain bug in the field.

BIRDS.

The Bureau of Biological Survey reports that *Chlorochroa sayi* has been found in the stomachs of the nighthawk (*Chordeiles virginianus*) and the meadowlark (*Sturnella neglecta*), and that individuals of other species of the same genus have been found in the stomachs of the bobwhite (*Colinus virginianus*), kingbird (*Tyrannus tyrannus*), Brewer blackbird (*Euphagus cyanocephalus*), Franklin gull (*Larus franklini*), and English sparrow (*Passer domesticus*).

MISCELLANEOUS ENEMIES.

The Rocky Mountain toad (*Bufo lentiginosus woodhousei*) has been recorded by the Biological Survey as feeding upon various species of Chlorochroa.

A half-grown chicken devoured 8 adults during a single day, when placed in a large outdoor cage with these insects. It has been commonly reported by farmers that a diet of grain bugs often kills barnyard fowls, but these reports have not been verified.

CONTROL METHODS.

DESTRUCTION OF HIBERNATING QUARTERS.

The obvious method for controlling the grain bug is the destruction of the adults when they are concentrated in their hibernating quarters. This is best accomplished in the late autumn, during the winter, or in the early spring by plowing under or burning all weeds and rubbish in and about cultivated fields. This applies particularly to the dead Russian thistle in abandoned fields and along irrigation ditches, check ridges, and fence rows; in fact, all locations where the accumulations of weeds or rubbish afford suitable hibernating quarters. Even in the large-scale farming operations which predominate throughout most of the territory infested by the insect, it is possible to carry out these measures of control as a good farming practice which contributes to the destruction of weeds and of various species of noxious insects. Much of the local infestation results from hibernating adults that wintered in the same field or its vicinity and which could have been destroyed by the farmer with an expenditure of very little additional labor. In many instances, however, the grain bug adults migrate from considerable distances and this circumstance necessitates a systematic clean-up community campaign in badly infested areas. Objections often are offered to control measures similar to the foregoing, because of the time and expense involved in their application, but it must be borne in mind that any extra efforts required to prevent insect depredations are repaid manyfold in the increased production of the crops. The measures recommended herein for the control of the grain bug should be included in good farm practice at any event and can be carried out during a time when farm labor and equipment ordinarily are idle.

TRAP CROPS.

Early in the season the immature stages of the first generation of the grain bug are concentrated on the tender plants of Russian thistle and other native plants growing in the waste areas of cultivated fields. At this time the multiplication of the species may be restricted greatly by spraying these areas with a strong insecticide or chemical, thus killing the insects and their obnoxious food plants in one operation.

HAND PICKING.

Hand picking of the grain bug adults and nymphs may possibly prove practical when valuable crops growing on small areas are attacked. These conditions often occur in the high-priced irrigation areas of the Southwest.

HOPPERDOZERS.

It has often been suggested that a hopperdozer might be employed to collect the adults and nymphs of the grain bug while they are feeding on the heads of the grain. An operation of this kind, however, would be complicated by the fact that the insects generally drop to the ground when closely approached. Then, too, at the time when most of the injury by the grain bug occurs the condition of the grain is such that the passage of any collecting machine would result in considerable damage to the crop.

A modification of the hopperdozer might be effective when the attacked crops are grown in hills or rows.

ASSOCIATED SPECIES OF PLANT BUGS.

A few nymphs and adults of *Thyanta custator* Fabr., *Thyanta rugulosa* (Say) Uhl., and several species of the genus Euschistus generally were found associated with *Chlorochroa sayi* in the field and closely resembled the latter in their life history and habits. None of these species was present in sufficient numbers to cause appreciable damage in the section of the country where these observations were made.

SUMMARY.

1. Since 1911 the grain bug (*Chlorochroa sayi* Stål) has become a serious enemy of wheat and other small grains in the intermountain and southwestern States.

2. The most important damage is caused by the insect piercing the newly formed heads of various cereals and removing the liquid contents, thus preventing the formation of the grain or greatly reducing its weight.

3. The reduction in yield from grain-bug attack varies from 10 to 50 per cent of the crop. In extreme cases the entire crop may be destroyed.

4. The cultivation of large areas formerly devoted to grazing eliminated the native food plants of the insect and caused it to attack cultivated plants.

5. This change to more succulent food plants, together with the superior facilities afforded for hibernation in the cultivated areas, resulted in an increase of the pest beyond its former abundance.

6. Wheat, barley, and rye are the preferred food plants among the cultivated crops. The species also feeds upon other cereals, and upon alfalfa, cotton, peas, beans, cabbage, tomato, and lettuce, in addition to many native plants.

7. The first recorded damage occurred in 1903, and since that time destructive outbreaks have been reported from most of the States west of the Great Plains area.

8. Weather influences and the work of parasites generally restrict destructive outbreaks in each locality to periodic intervals of two or three years.

9. Adults emerge from hibernation in the early spring and deposit eggs on the material composing the hibernating quarters. The resulting nymphs feed upon tender plants growing in the vicinity.

10. Upon reaching maturity the adults migrate to grain fields and feed upon the developing heads.

11. There are three distinct generations and sometimes a partial fourth generation annually. About 50 days are required to complete the life cycle of each generation.

12. After midsummer the numbers of the insects are greatly reduced by an egg parasite, *Telenomus ashmeadi*, and by two species of tachinid parasites, *Gymnosoma fuliginosa* and *Ocypterodes euchenor*, which parasitize the adults. Several kinds of predacious enemies contribute to the same result.

13. Hibernation occurs in the adult stage under weeds or rubbish. No nymphs or eggs survive the winter.

14. Severe winters result in the death of a large percentage of hibernating adults and constitute one of the most important factors in restricting destructive outbreaks of the species. During normal winters at least 95 per cent of the adults survive when hibernating in protected locations.

15. The most effective and practical method of control is the destruction of the adults while they are concentrated in their winter quarters. This is best accomplished by plowing under, or burning, all rubbish and weeds, particularly Russian thistle, in and about cultivated fields. These control measures should be included as a part of the regular farm practice and any special work required may be carried on during the inactive season at a time when the farm labor and equipment ordinarily are idle.

16. Trap crops, hand picking, and hopperdozers might prove practical in the control of the insect under special conditions.

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